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(54) IMPROVEMENTS IN OR RELATING TO FLAT ELECTRIC CABLES

(71) We, WESTERN ELECTRIC COMPANY INCORPORATED, of 195, Broadway, New York City, New York State, United States of America, a Corporation organised and existing under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to flat electric cables.

In the field of interconnection, which largely involves massive wired connections between numerous sub-assemblies of complex electronic gear such as computers, etc., the concept of flat cable has recently received much attention because of its mass termination and rearrangement cost benefit. Mass terminations also result in fewer wiring errors which is an important consideration for such complex systems.

The problem of crosstalk between adjacent paths of flat cable has been recognized. One solution is to place conductors of a given pair on opposite sides of the insulative circuit carrier, with their paths slightly and oppositely offset with respect to a common nominal path locator. The offsets are periodically reversed, so as to achieve what has been called a "pseudo-twist", and the twist length between adjacent pairs are selected to minimize crosstalk.

Use of different twist lengths in a pseudo-twisted multipair flat conductor cable normally causes the characteristic impedance and propagation velocity to differ from pair to pair. The remedy for this situation is not found by reference to the conventional continuously twisted pair art because of the peculiarities of flat conductors and the non-helical twists of the pseudotwist structure.

According to the invention a flat electric cable includes a plurality of pairs of conductive paths, said pairs being arranged in side-by-side relation, and insulative means between the paths of each said pair, one path of each said pair crossing over the other path thereof at intervals different from pair-to-pair, and the area of overlap at each crossover being different from pair-to-pair, the cable being such that each said pair has substantially the same propagation velocity and characteristic impedance as each of the other pairs.

Preferably, said insulative means comprises a unitary insulative medium, and one path of each said pair is disposed on one side of said insulative medium and the other path thereof is disposed on the opposite side of said insulative medium. Said insulative means may be flexible.

The invention will now be described with reference to the accompanying drawing in which:

Fig. 1 is a schematic perspective drawing of a flat cable with different twist lengths;

Fig. 2 is a schematic top view of crossover points between conductors of a given pair in such a cable;

Figs. 3A and 3B illustrate crossover points sized with respect to Fig. 2; and

Fig. 4 is a graph showing the relationship between capacitance per unit length vs. twist length.

Fig. 1 shows a flat cable 10 having "pseudotwisted" pairs 11—15. The two conductive paths which make up each pair are denoted a and b in each case. The a paths are all disposed on one side of a flexible insulative medium 16, and the b paths are disposed on the opposite side of medium 16. Crossover regions 17 occur along each pair 11—15. Each pair is given a different twist length with the ratio selected to minimize crosstalk between adjacent pairs. These different twist lengths are achieved by causing the paths to undergo juxtaposition reversals of differing periodicity from pair to pair. Except for the space in which the reversals occur, the paths of each pair and all pairs are generally parallel.

Fig. 2 depicts a generalized pseudotwisted pair with a twist length generally denoted l defined as the distance between centres of two adjacent crossovers 17a, 17b. The two

conductor paths 18, 19 which make up the pair are applied by any of various conventional methods to opposite sides of insulative medium 16. The two crossover areas shown as 17′ are regions of overlap between the paths 18, 19.

At frequencies in the megahertz region, the characteristic impedance Z_o and the propagation velocity μ of any given line are; respectively,

$$Z_o = \sqrt{L/C} \qquad (1)$$

and

$$\mu = \frac{1}{\sqrt{LC}} \qquad (2)$$

where L and C in both equations are the inductance per unit length and the capacitance per unit length, respectively.

For pseudotwisted flat cable such as shown in Figs. 1 and 2, Z_o and μ are additionally functions of the twist length *l*. This is because of the lumped capacitance denoted C_2 associated with the crossover areas 17′. To a first approximation:

$$C_2 \alpha d^2 \qquad (3)$$

where *d* is the lateral width of the conductive paths as shown in Fig. 2.

Fig. 4 plots the measured capacitance in picofarads per foot for differing values of twist length *l* for a pseudotwisted pair having a fixed path width *d*. However, it will be recognized that the per-unit length inductance L_1 and capacitance C_1 of the pair in Fig. 2 are substantially independent of path width *d*. Further, decreasing the twist length by a factor of 2, for example, increases the contribution of the capacitances C_2 also by a factor of 2.

This can be exactly compensated for by reducing the path width *d* by a factor of $\sqrt{2}$ in the above example. It follows that Z_o and μ are then rendered independent of the twist length *l*. In general, the crossover area 17′ is made smaller for shorter twist lengths and larger for greater twist lengths.

Table 1 (see hereinafter) illustrates by way of example how the path width may be varied to compensate for different twist lengths so that all pseudotwist pairs of a given cable will exhibit the same characteristic impedance Z_o and propagation velocity μ. It has been found that a variation of from 1/2″ to 8″ in the twist length *l* occasions a change in the unit length inductance L of less than ten percent, hence making it possible to concentrate solely on control of the contributions of the crossover area capacitances C_2.

TABLE 1

Varying path width *d′* to compensate for twist length *l*

l	*d′*
8″	.050″
4″	.050″/√2=.035″
2″	.035″/√2=.025″
1″	.025″/√2=.018″
1/2″	.018″/√2=.012″

Figs. 3A and 3B depict two specific approaches to vary the crossover area in practice. In Fig. 3A the accessary reduction in the path width *d* to a value *d′* is made, and the crossover legs 20, 21 are maintained at the width *d′* until an intersection is effected. In Fig. 3B, the width of the crossover legs 20, 21 are held at the same width *d* as that of the main circuit paths until approach to the crossover area is made. The path width is, then abruptly reduced to a value *d′*. Other methods can readily be envisioned that will achieve the required reduction in path width at the crossover point so as to reduce the crossover area, and hence the capacitances C_2.

In manufacturing flat cable, all of the pair paths may advantageously be constructed with substantially the same standard width along the parallel portions. Then, the crossover regions of all but one of the cable pairs are constructed using path widths less than the standard width by an amount dependent on the juxtaposition reversal periodicity of the given pair.

For high pair count flat cables, with a large number of twist lengths, it may be desirable to supply some crossover areas which are greater than can be made with the standard path width, as well as having crossover areas reduced from the standard path width, to avoid potential problems incident to very small crossover areas.

The invention has been described largely in its use with a flexible insulative medium which may, for example, be Mylar (Registered Trade Mark) or the like with copper conductor paths made using either metal deposition or etching techniques. It is, however, obvious that the invention is also applicable to multipair configurations produced on inflexible media.

WHAT WE CLAIM IS:—

1. A flat electric cable including a plurality of pairs of conductive paths, said pairs being arranged in side-by-side relation, and insulative means between the paths of each said pair, one path of each said pair crossing over the other path thereof at intervals different from pair-to-pair, and the area of overlap at each crossover being different from pair-to-pair, the cable being such that each said pair has substantially the same propagation velo-

city and characteristic impedance as each of the other pairs.

2. A flat electric cable as claimed in claim 1 wherein said insulative means comprises a unitary insulative medium, and one path of each said pair is disposed on one surface of said insulative medium and the other path thereof is disposed on the opposite surface of said insulative medium.

3. A flat electric cable as claimed in claim 1 or 2 wherein said insulative means is flexible.

4. A flat electric cable substantially as herein described with reference to Fig. 1 with Fig. 3A or 3B of the accompanying drawings.

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1 SHEET This drawing is a reproduction of the Original on a reduced scale

Fig. 1.

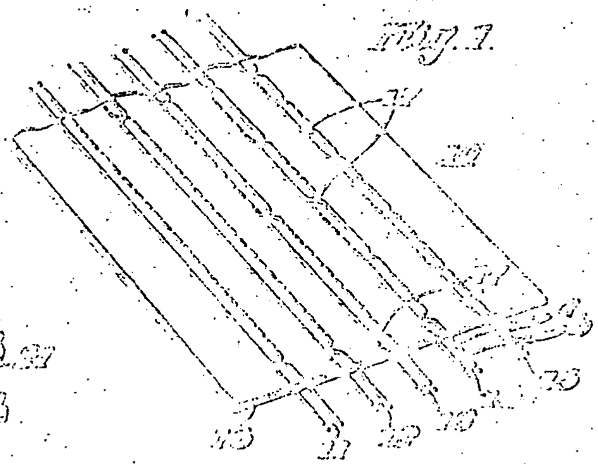

Fig. 2a.

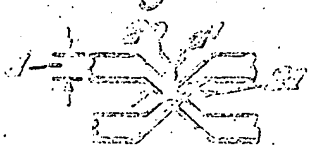

Fig. 2.

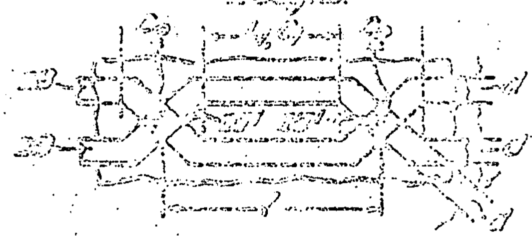

Fig. 3a.

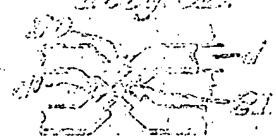

Fig. 4.